Characteristic X-ray spectral variations in the iron L-band of IRAS 13224-3089, 1H0707-495 and NGC 4051

Misaki Mizumoto (JAXA/ISAS, Univ. of Tokyo)

Ken Ebisawa (JAXA/ISAS), Hiroaki Sameshima (Kyoto Sangyo Univ.),
Hiroki Yamasaki (JAXA/ISAS)

Breaking the limits (2016.9.19-23 @Sardegna)

RMS spectra (Yamasaki, MM et al. 2016 PASJ)

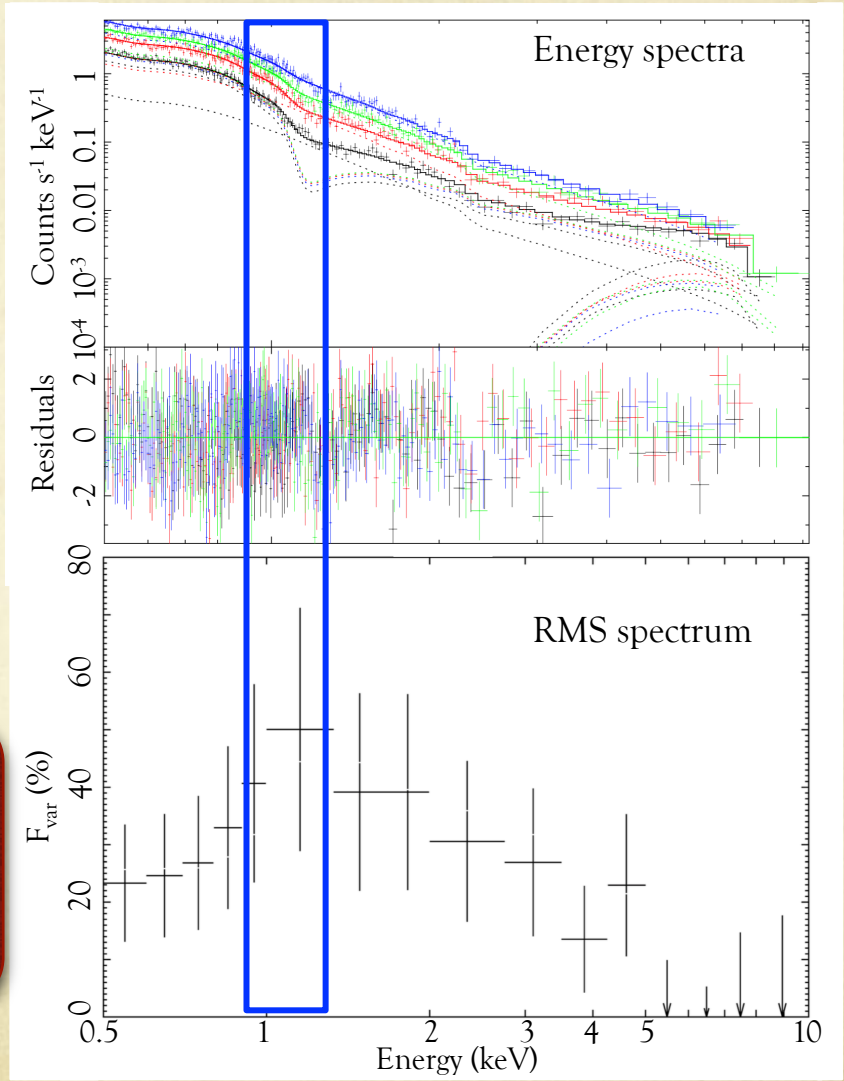
- Root-mean-square (RMS) spectrum

$$F_{\mathrm{var}} = \frac{1}{\langle X \rangle}\sqrt{S^2 - \langle \sigma_{err}^2 \rangle}$$

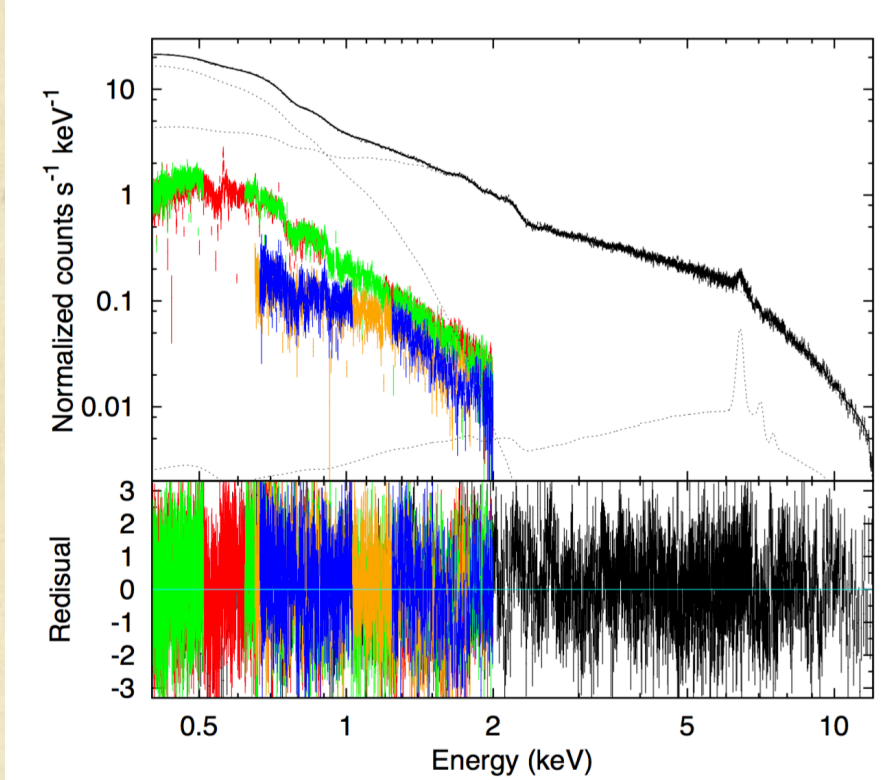
where $\langle X \rangle$ is the mean count rate,
S^2 is the variance of the light curve,
$\langle \sigma_{\mathrm{err}}{}^2 \rangle$ is the mean error squared.

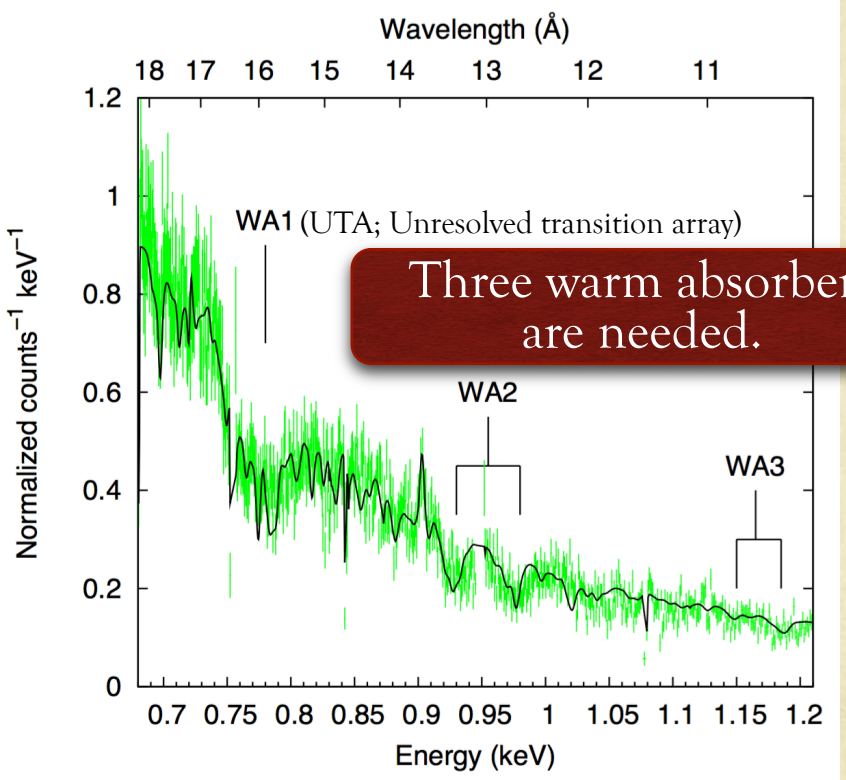
- IRAS 13224-3809
  - strong iron K- and L-edges

A strong RMS feature is seen at the Fe-L energy band.



NGC 4051 (MM, Ebisawa 2016, submitted)





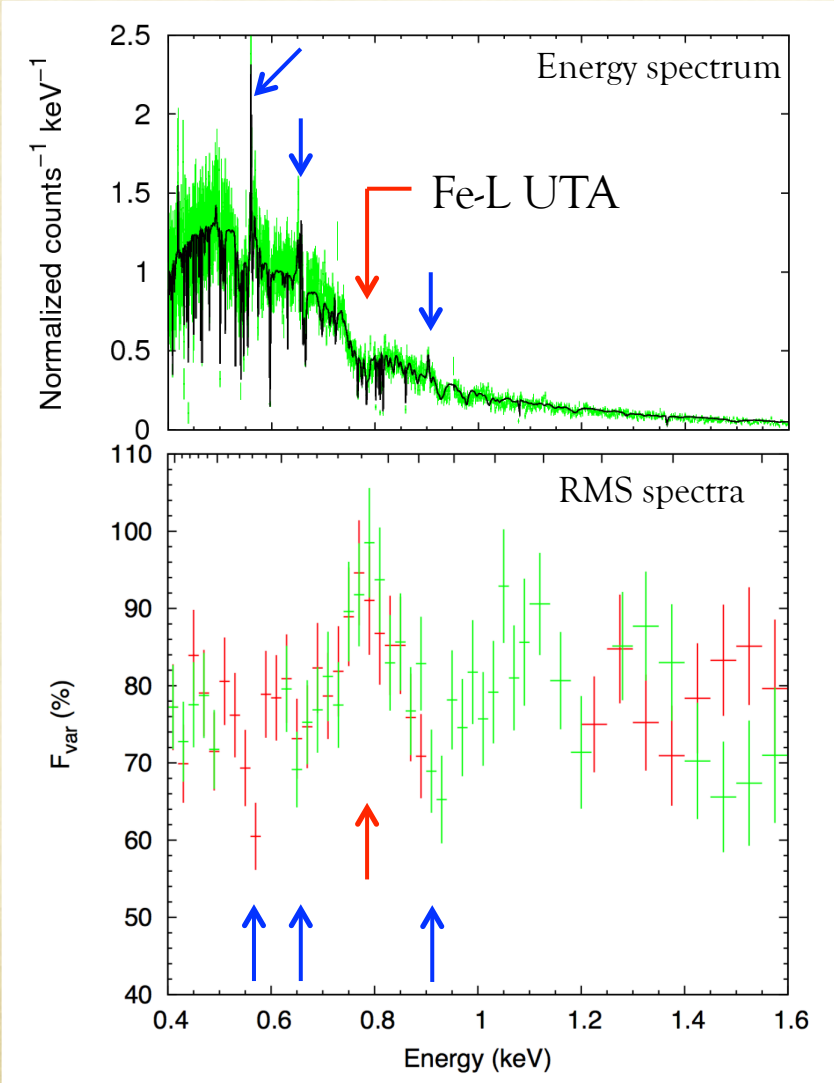
Three warm absorbers are needed.

- Long exposure (600ks XMM observation in 2009)
- Strong Fe-L absorption feature
  → Best target
- Tbabs×{(MCD+PL)×WA1×WA2×WA3+reflection}

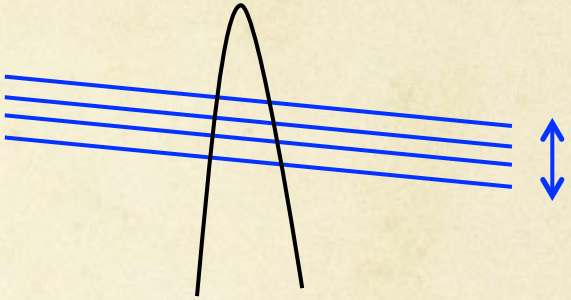
	N_H (cm^{-2})	log ξ	v (km/s)
WA1	2.5×10^{21}	1.5	-650
WA2	8.7×10^{21}	2.5	-4000
WA3	6.7×10^{23}	3.4	-6100

RMS spectra

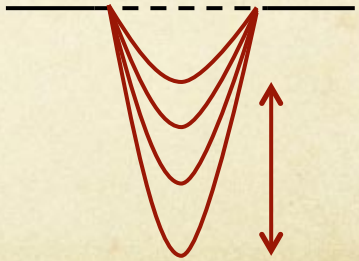
NGC4051



Non-variable emission lines
--> RMS dips

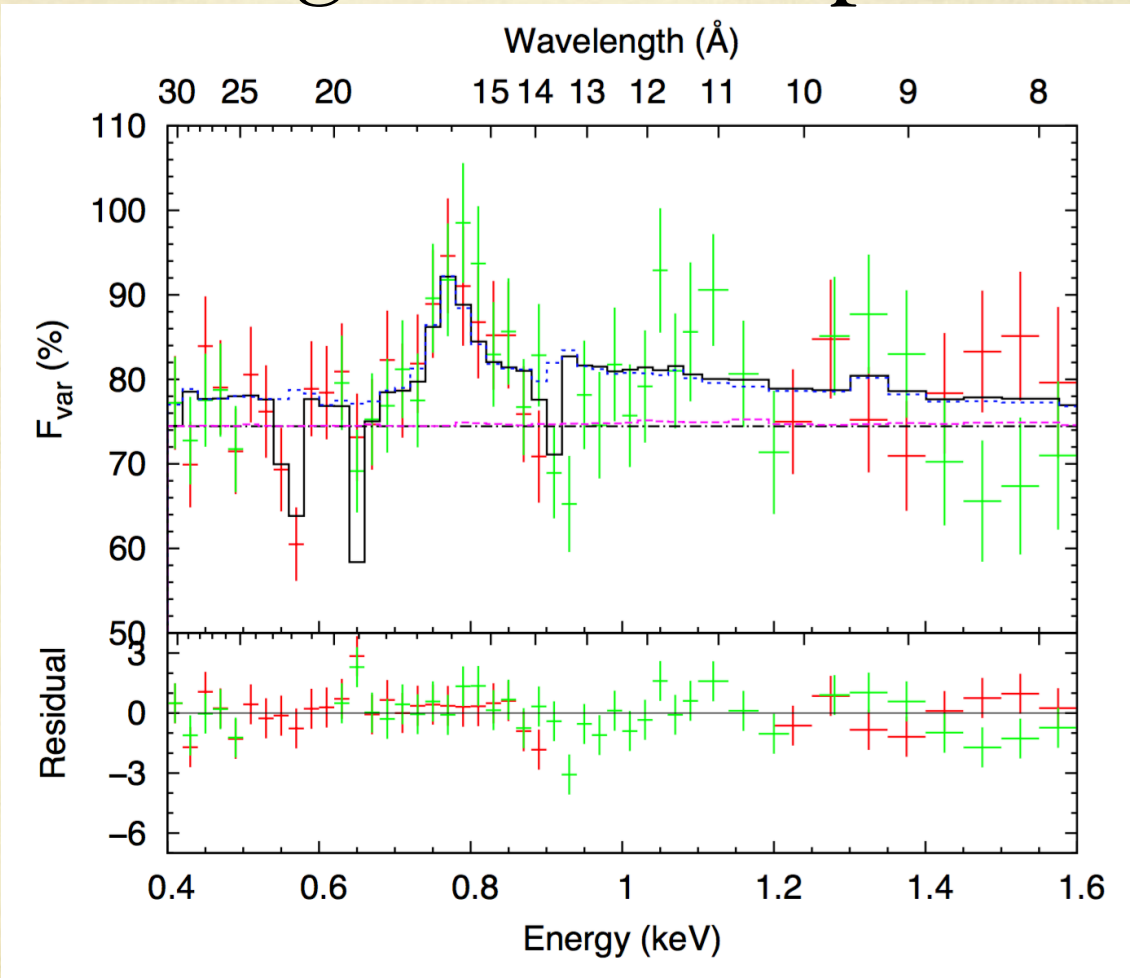


Variable absorption lines
--> RMS peaks



Fe-L UTA is variable.

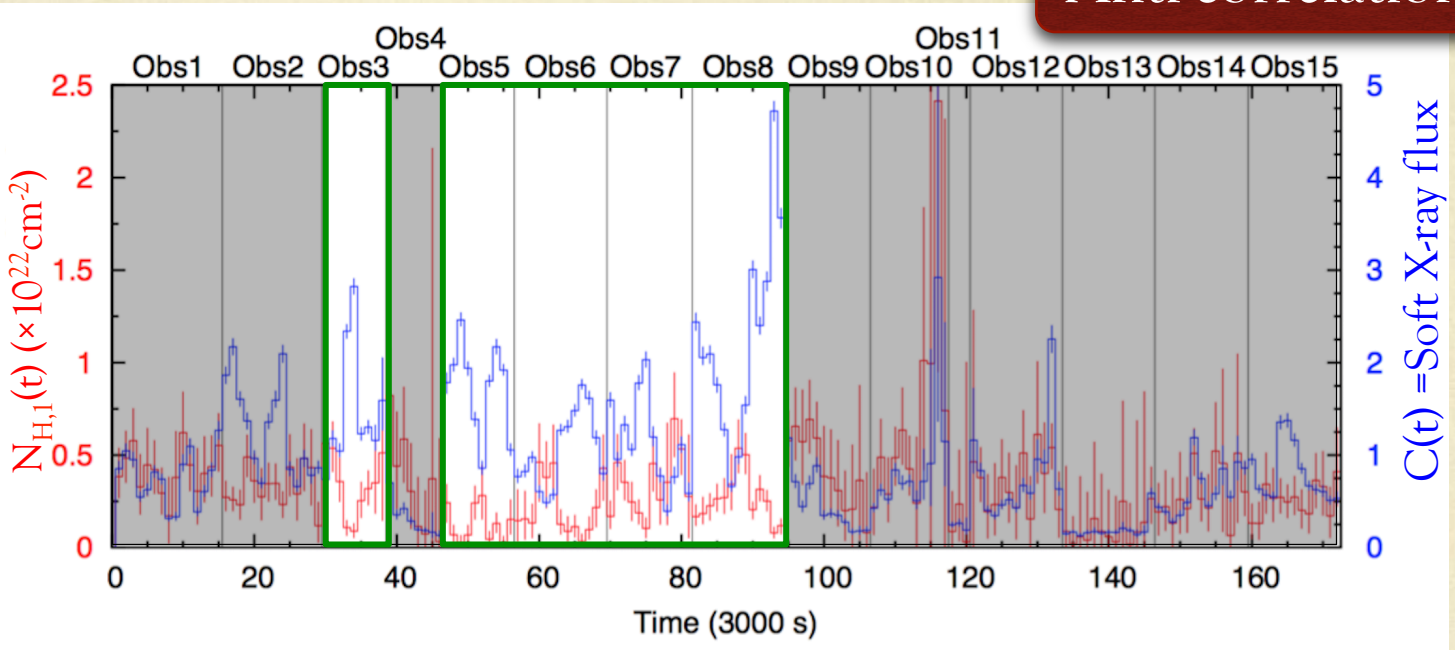
Fitting of RMS spectra



Only WA1 is variable,
whereas WA2, 3 are not variable.

Time variations

Anti-correlation



Create time-sliced spectra of RGS (< 2 keV) with 3000s, and fit them with

Tbabs(E) ×{(MCD(E)+PL(E)) ×C(t) ×WA1(E,t) ×WA2(E) ×WA3(E) +Reflection(E)}

- C(t): Variation of the continuum (= Variation of the soft X-ray flux)
- WA1(E,t) =exp[$-\sigma_1(E)N_{H,1}(t)$]

Interpretation of the model

Tbabs(E) ×{(MCD(E)+PL(E)) ×C(t) ×WA1(E,t) ×WA2(E) ×WA3(E) +Reflection(E)}

Variation of soft X-ray flux
→Partial covering of Compton-thick clouds (W_{thick})
(e.g. Pounds et al. 2004, Lobban et al. 2011)

$$C(t) = 1 - \alpha(t)$$
$$= 1 - \alpha(t) + \alpha(t) W_{thick}(E)$$
(=0 when E<2 keV)

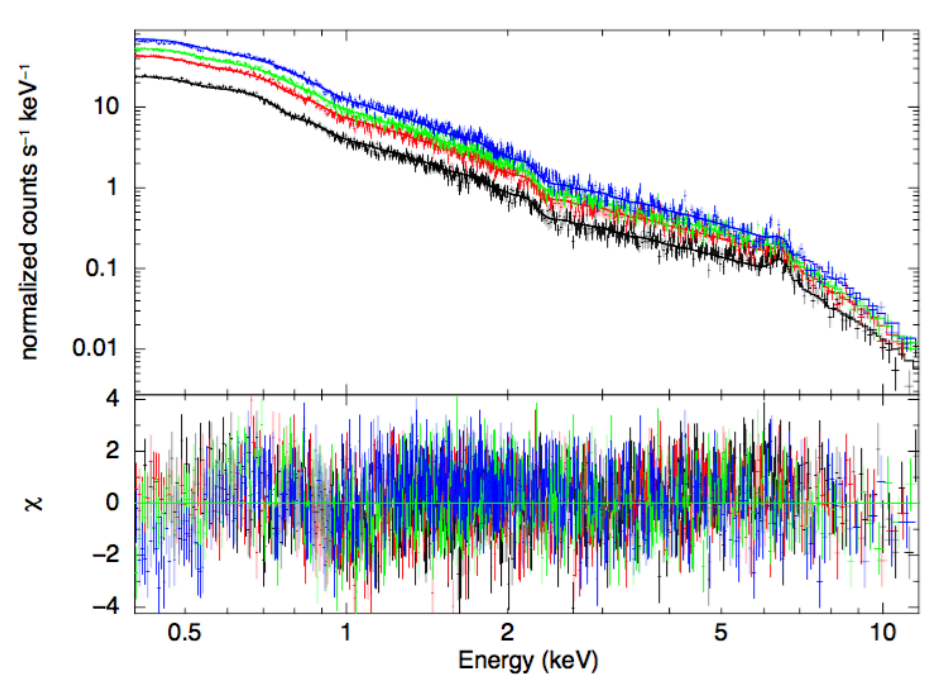
Variation of N_H of WA1
→Partial covering of optically-thin clouds
(Mizumoto et al. 2014)

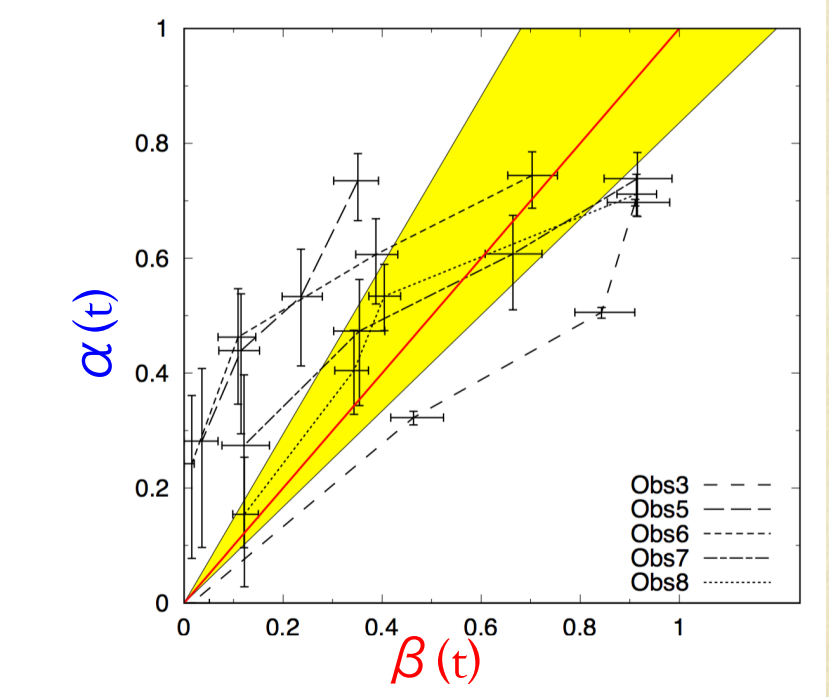
$$\mathrm{WA1}(E,t)$$
$$= \exp[-\sigma_1(E) N_{H,1}(t)]$$
$$\approx 1 - \sigma_1(E) N_{H,1}(t) \qquad (\text{when } \sigma N_H << 1)$$
$$= 1 - \sigma_1(E) \beta(t) N_{H,1}^{fixed}$$
$$= 1 - \beta(t) + \beta(t)(1 - \sigma_1(E) N_{H,1}^{fixed})$$
$$\approx 1 - \beta(t) + \beta(t) \exp[-\sigma_1(E) N_{H,1}^{fixed}]$$
$$= 1 - \beta(t) + \beta(t) \mathrm{WA1}(E)$$

Double partial covering

Tbabs(E) ×{(MCD(E)+PL(E)) ×(1-α(t) + α(t)W_{thick}(E))
×(1-β(t)+ β(t)WA1(E)) ×WA2(E) ×WA3(E) +Reflection(E)}

Intensity-sliced spectra

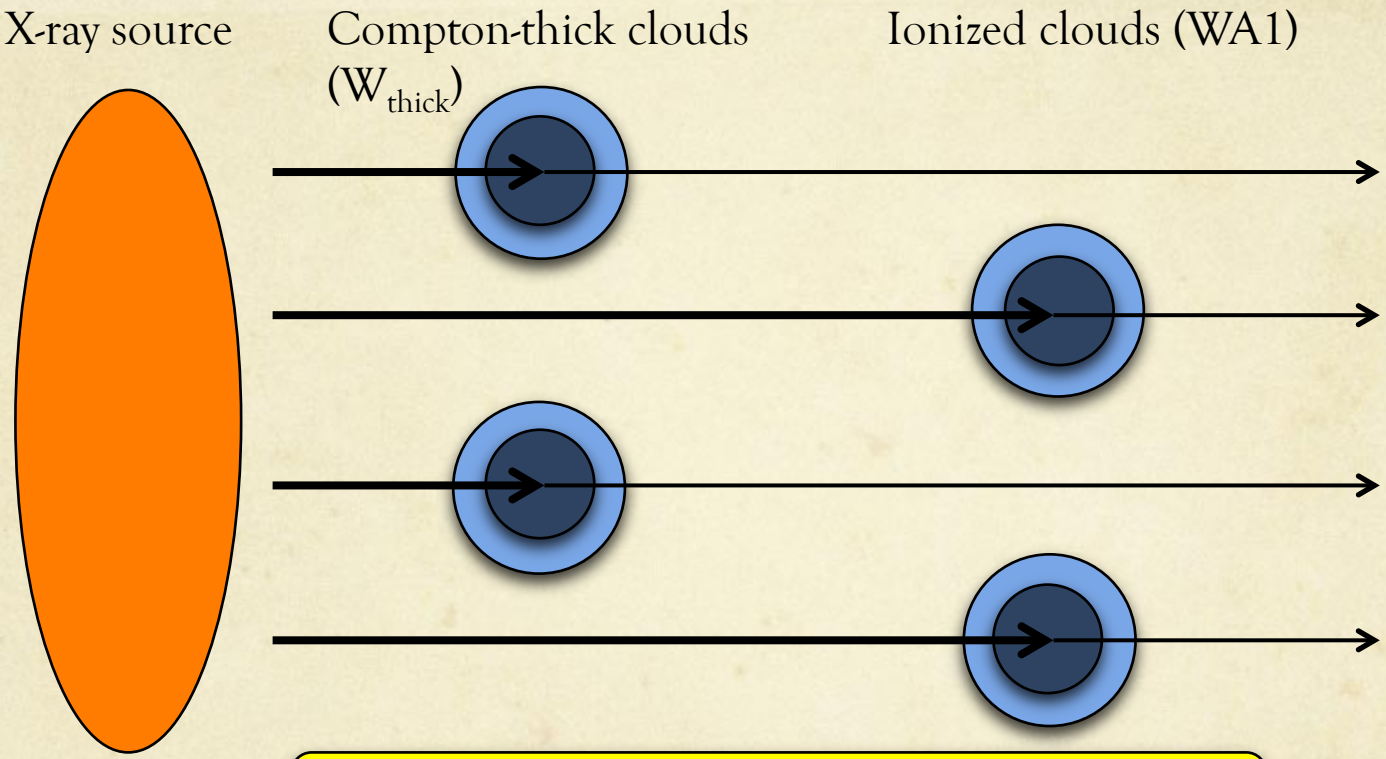




Tbabs(E) ×{(MCD(E)+PL(E)) ×(1-α(t) + α(t)W_{thick}(E))
×(1-β(t) + β(t)WA1(E)) ×WA2(E) ×WA3(E) +Reflection(E)}

The two partial covering fractions are equal.

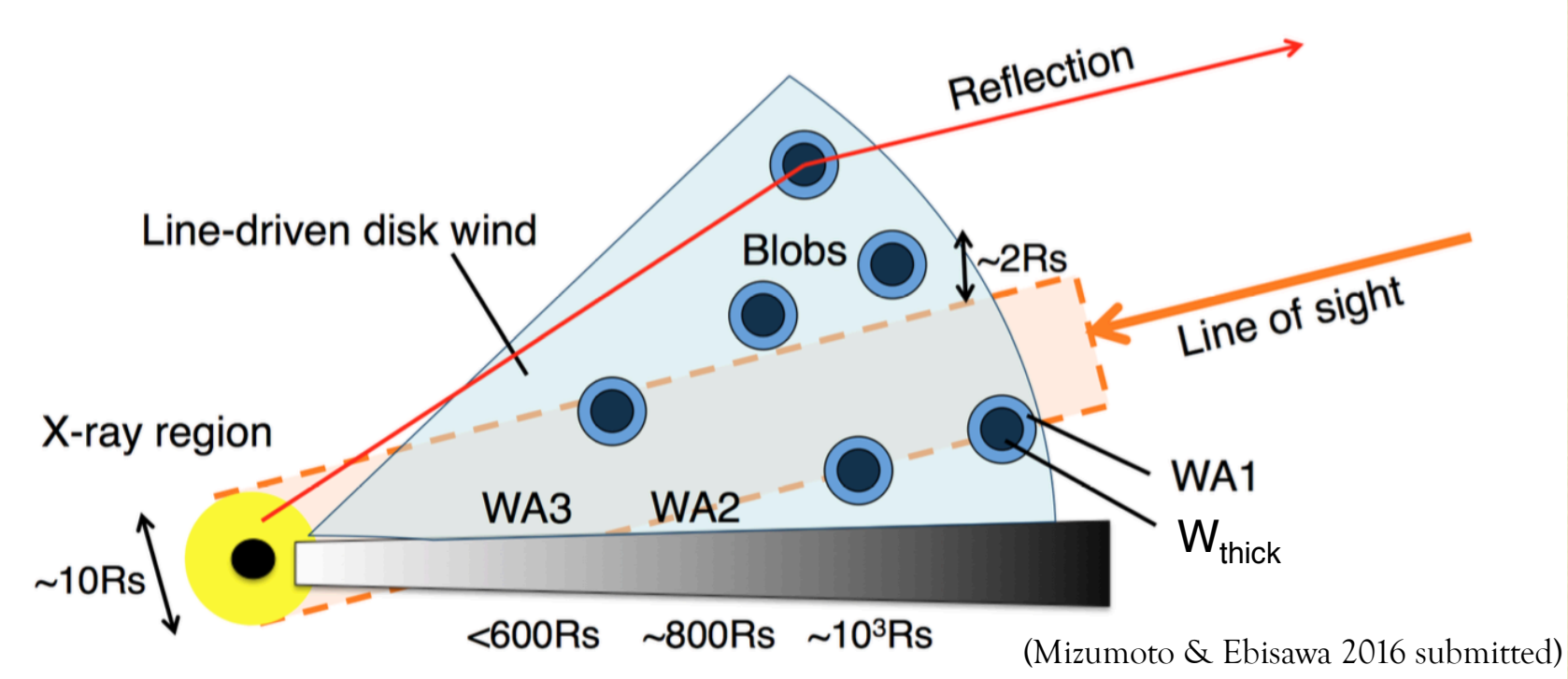
Double partial covering



Partial covering fractions are equal.

Partial covering of double-layer clouds

Geometry of WAs in NGC 4051

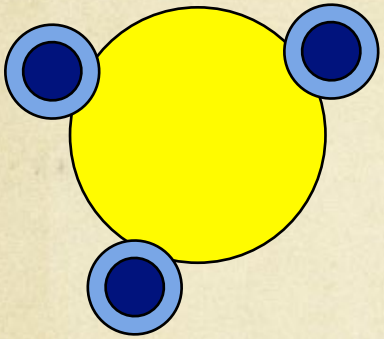


(Mizumoto & Ebisawa 2016 submitted)

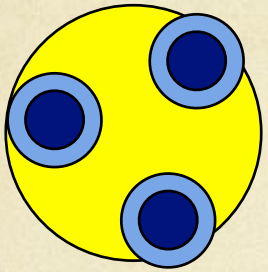
WA1 and W_{thick} create
partial covering clouds with double-layer
(Dusty wind?)

WA2,3 show no variability
→extended in the line of sight

RMS peaks of IRAS 13224 and 1H0707

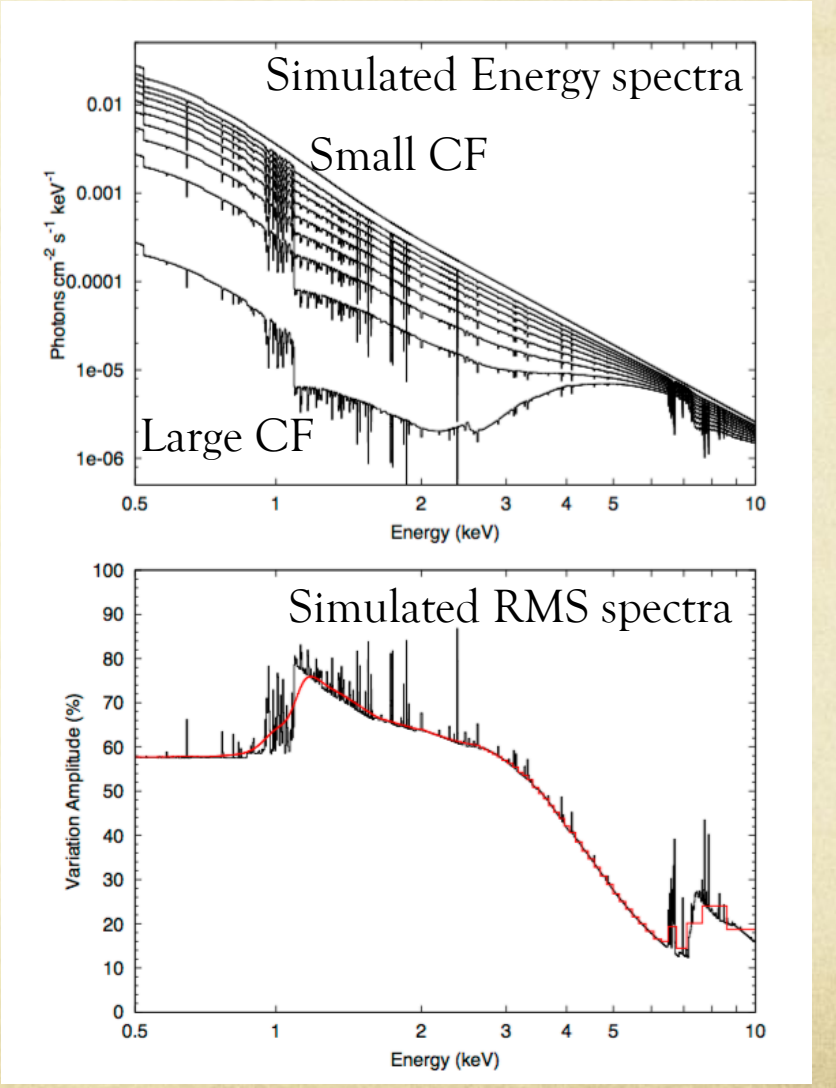


Small covering fraction
→Bright X-ray flux
Weak Fe-L edge



Large covering fraction
→Faint X-ray flux
Strong Fe-L edge

Partial covering of double-layer clouds can explain the RMS spectra



IRAS13224 (Yamasaki, MM, et al. 2016)